Land Use Influence on Fish Communities in Central Indiana Streams

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Abstract
In recent years a number of large rivers including the Ohio and Wabash Rivers have experienced better environmental conditions and fish communities principally because of improvements in point-source discharges. Further progress is not likely to occur until NPS sources are reduced. The trends in smaller streams in agricultural landscapes are less encouraging. The fish communities in several stream systems in the Wabash River drainage have undergone sharp changes in character during the past decade or two. The sequence of change is a sudden loss of darters, followed by the disappearance of centrarchids, and then smallmouth bass. In extreme cases this is followed by a loss of Moxostoma species and a variety of minnows as more and more of the watershed is converted to tilled fields. Sporadic spills of fertilizer and feed lot wastes no doubt accelerate and confound the overall trends. The changes are not gradual and linear. The presence of "good" refugial tributaries permits a natural "reseeding" during benevolent years. The trends observed suggest that streams which have only recently lost their smallmouth bass populations may be rehabilitated with relatively modest effort and expense.

Introduction

The influence of agricultural on Indiana streams can be roughly categorized into (a) point source influences such as animal feed lots and fertilizer spills and (b) non-point source (NPS) influences including tilled fields and pastures.

Agriculture occupies 70% of Indiana lands and 78% of this land is devoted to rowcrop agriculture (55% of Indiana), mostly corn and soybeans. Of the estimated 108 million tons of soil annually eroded from Indiana land, nearly four-fifths (79%) originates from tilled fields that occupy slightly more than half of Indiana. Perhaps the Illinois rule-of-thumb estimate states the problem most succinctly: for every bushel of corn harvested, two bushels of soil are lost.

It is difficult to convince most people, including farmers, politicians, and engineers, that soil is a pollutant although they might readily agree that pesticides, herbicides, and fertilizers do pollute water. It is also extremely difficult to document the chronic effects of NPS pollution apart from the sporadic fish kills caused by specific agricultural activities.

In recent years, a number of large rivers including the Ohio and Wabash Rivers have experienced better environmental conditions and improved fish communities principally because of refinements in waste treatment of point-source discharges. Further progress is unlikely until NPS contributions are reduced. In the Wabash River the number of catchable game fish is more than 10 times as great as it was in the 1970's and the non-game species have similarly increased. Furthermore, the size of fish is bigger. About the only species which have declined are carp and gizzard shad. For the first time in over 20 years, predator fishes in the Wabash River are numerous enough to control gizzard shad.

Why this rather sudden improvement? It is partly because of improved waste treatment of towns and industries within the basin. Decomposable organic matter (BOD) today is only 2.5 to 3.0 mg/l today compared to 4.5 to 5.0 mg/l 15 years ago (Gammon 1989). That translates into better oxygen condi-

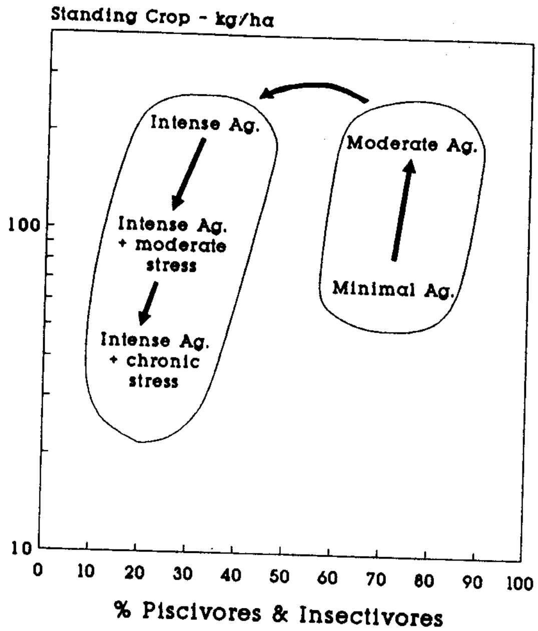

Figure 1: Changes in the fish communities of central Indiana streams under agricultural development.

tions through reduced dissolved oxygen deficits. An additional contributing factor might well be the 1983 PIK program, a year during which 25% less corn and soybeans were grown with concomitant reductions in applications of herbicides and pesticides.

In order to further improve river ecosystems nutrient delivery to the river must be reduced. Half of the carbonaceous BOD entering the middle Wabash is estimated to come from agriculture (HydroQual 1984). Phytoplankton, mostly diatoms, colors the Wabash River brown during the summer with as much as 100,000 algal cells per ml and chlorophyll-a concentrations exceeding 150 ug/l. High densities of algae produce two undesirable ecological effects: (a) the dissolved oxygen level is depressed at night and (b) the turbidity interferes with the ability of predator fish such as bass and walleye to locate food. In one segment of the Wabash it has also caused fishkills on at least two occasions (Parke 1985, Parke and Gammon 1986). There is also an undesirable recreational effect. Few people care to swim, canoe, or fish in turbid rivers which are perceived as being "dirty".

The trends of fish communities in smaller streams in Indiana's agricultural landscapes are quite different and not nearly as encouraging. Some are known to have undergone sharp changes in character during the past decade or two. It is likely that others are going to follow suit or, perhaps, have already done so without our knowledge.

The pattern of change was demonstrated during a Model Implementation Project study of three central Indiana stream systems (Gammon et. al. 1983). Moderate agricultural development of a watershed may only result in an increase in fish standing crop with no measureable change in the darter, sunfish, and bass components of the community (Figure 1). Further agricultural expansion, however, ultimately results in a sudden loss of darters, centrarchids, and possibly catostomids with expansions of omnivores and detritivores. Further changes occur through the loss of Moxostoma species (redhorse) and a variety of minnows as more and more of the watershed is converted to tilled fields. The changes occur first in smaller streams and then progress downstream.

Methods and Materials

The streams discussed in this paper are located in rural areas of Indiana and are not influenced strongly by industry, mining, or municipalities (Figure 2). The fish communities of most of the included streams have been intensely examined at multiple stations over several years during the past 12 years. Stream segments measurably influenced by towns or industries have been excluded from the analyses.

Methods of collecting fish vary with size of stream. A seine and backpack electrofisher were used in most small second and third order streams. Larger streams were electrofished with an electric seine, a backpack electrofisher carried in a boat, and/or a seine in shallows areas.

Data on agricultural landuse was obtained variously from (a) estimates by Soil Conservation Service personnel, (b) detailed computer analysis of LandSat imagery (Hyde, Goldblatt, and Stolz 1982), and (c) conventional analysis of enlarged LandSat infrared photographs taken during early summer, as described below.

Using topographic maps of the stream or tributary of concern, the drainage area perimeter was determined and drawn onto rescaled drainage maps (Hoggatt 1975). An infrared LandSat photograph taken on June 10, 1978 provided good contrast of permanent vegetation as grass or trees (red) from tilled field (tan and black). After establishing the best darkness setting the watershed of interest was xeroxed to produce an acceptable dark copy of the red portions in contrast to the lighter portions.

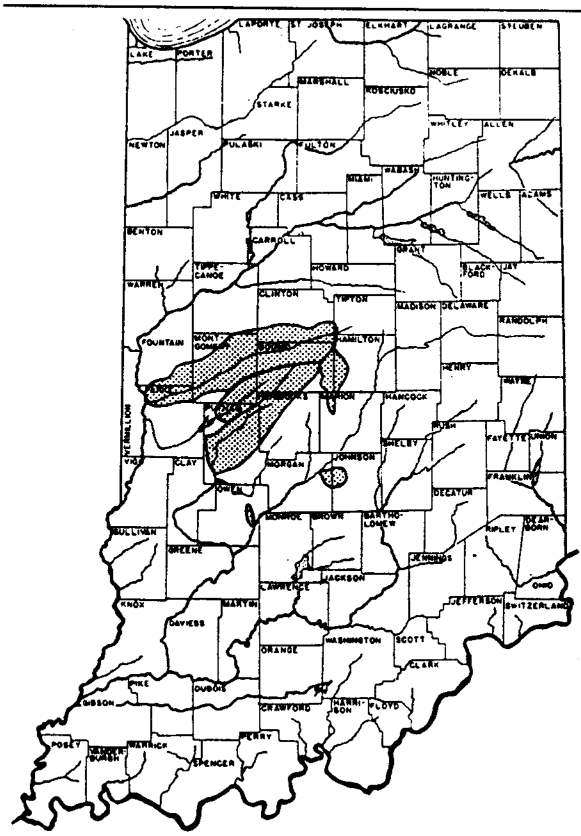

Figure 2: Location of Study Streams.

This xerox copy was superimposed over the scaled drainage maps on a light table, the drainage basin boundary was traced onto the xerox copy, and enlarged to 150%. This copy was placed over a fine transparent grid on a light table. If single grids contained more than 50% vegetation a mark was made. The total number of grids marked in relation to the total number of grids provided an estimate of the percentage of the drainage basin area in rowcrop agriculture.

Results

Data on the IBI of fish communities and the percent of watershed devoted to rowcrop agriculture are summarized in Table 1. A majority of streams flowed through watersheds with more than 65% of the area in row crop agriculture.

Discussion

The IBI should function well in assessing the degree to which stream fish communities are influenced by non-point source pollution because 5 of the 12 metrics include species sensitive to sediment pollution. The data from Table 1 was divided into two parts: (1) smaller streams (Orders I and II), and (2) larger streams (Orders III and IV). IBI values for the larger streams generally exceeded those for smaller streams, but there was considerable overlap. Studies in Ohio and Illinois indicate a direct relationship between stream order and IBI values (Ohio E.P.A. 1988, Hite and Bertrand 1989).

The IBI of the fish community and the percent of the watershed in rowcrop agriculture is summarized in Figure 3. The few watersheds having 50% or less of their areas in rowcrops contained fish communities with IBIs of 50 or greater. There was a statistically significant correlation (Spearman) at the 0.05 level between percent rowcrop

Table 1: Drainage basin area, agricultural land-use, and fish communities of central Indiana streams.

Stream	Stream Order	Drainage Basin Area km2	(mi^2)	% Rowcrop	IBI	Number of Species Dar.	Sun.	Bass
Sugar Creek System								
Mainstem								
Above Darlington	III	829	(320)		47.1[a]	2.0	0.9	0.5
Darl. to C-ville	IV	1318	(509)	75	49.7[b]	3.0	1.2	1.0
C-ville to mouth	IV	2100	(811)	60	48.0[c]	2.7	1.2	1.3
Tributaries								
Rush	I	42.2	(16.3)	64	44	2	0	0
Sugar Mill	II	197.4	(76.2)	69	42	1	0	2
Indian	II	65.5	(25.3)	70	38	1	3	1
Rattlesnake/	III	81.3	(31.4)	59	52	2	3	2
Offield	II			59	42	2	1	1
Black	II	90.4	(34.9)	66	40	3	2	1
Walnut Fork	II/III	117.3	(45.3)	71	42	3	3	2
Little Sugar	II/III	117.6	(45.4)	69	47	3	3	1
Lye	III	203.8	(78.7)	82	36.5	3	2	2
Wolf	II	65.8	(25.4)	74	52	4	5	1
Prairie	III	127.9	(49.4)	70	28	3	1	1
Big Raccoon Creek System								
Mainstem								
Montogomery Co.	III	251.0	(96.9)	80	42[d]	1	3	1
Ramp Crk. to Putnam line	III	365.2	(141)	71	43.1[e]	1.42	1.62	0.82
Tributaries								
Cornstalk	II	52.6	(20.3)	72	41	2	2	1
Haw	II	72.5	(28.0)	73	42	1	3	1
Ramp	III	85.7	(33.1)	62	52	5	1	1
Big Walnut Creek System								
Mainstem								
Above US 36	IV	357.6	(138)	81	50.2[f]	3.0	1.9	1.2
US 36 to G-castle	IV	575.0	(222)	67	48.5[g]	1.7	2.2	1.5
Eagle Creek System								
Mainstem - upper	III	74.1	(28.6)	74.4	48	4	5	2
Tributaries								
School Branch	I	22.7	(8.7)	73.6	46	4	3	1
Fishback	II	53.8	(20.8)	65.3	42	5	3	1
Little Eagle	II	75.9	(29.3)	72.4	46	4	3	1
Finley	I	25.2	(9.8)	72.1	48	4	2	0
Mount's Run	II	41.2	(15.9)	59.7	48	4	5	2
Stotts Creek System								
Mainstem	IV	155.6	(60.1)	58.4	48	3	3	2
North Fork								
lower	III	56.7	(21.9)	55.0	54	5	3	2
upper	II				43	5	3	2

Table 1 concluded.

South Fork							
lower	III	87.3 (33.7)	53.4	50	5	2	0
upper	II			44	2	2	0
Miscellaneous Streams							
Rattlesnake Creek	III	65.2 (25.2)	15?	53[h]	5	4.5	1.5
Stinking Fork	III	70.7 (27.3)	40?	50[i]	3.3	3	1.3

[a] Mean of 7 stations above Darlington.
[b] Mean of 4 stations between Darlington and Crawfordsville.
[c] Mean of 12 stations between Crawfordsville and the mouth.
[d] Mean of 3 stations.
[e] Mean of 8 stations over 8 years from 1981 through 1989.
[f] Mean of 8 stations from 1979 through 1984.
[g] Mean of 8 stations from 1979 through 1987.
[h] Mean of 2 stations.
[i] Mean of 4 stations

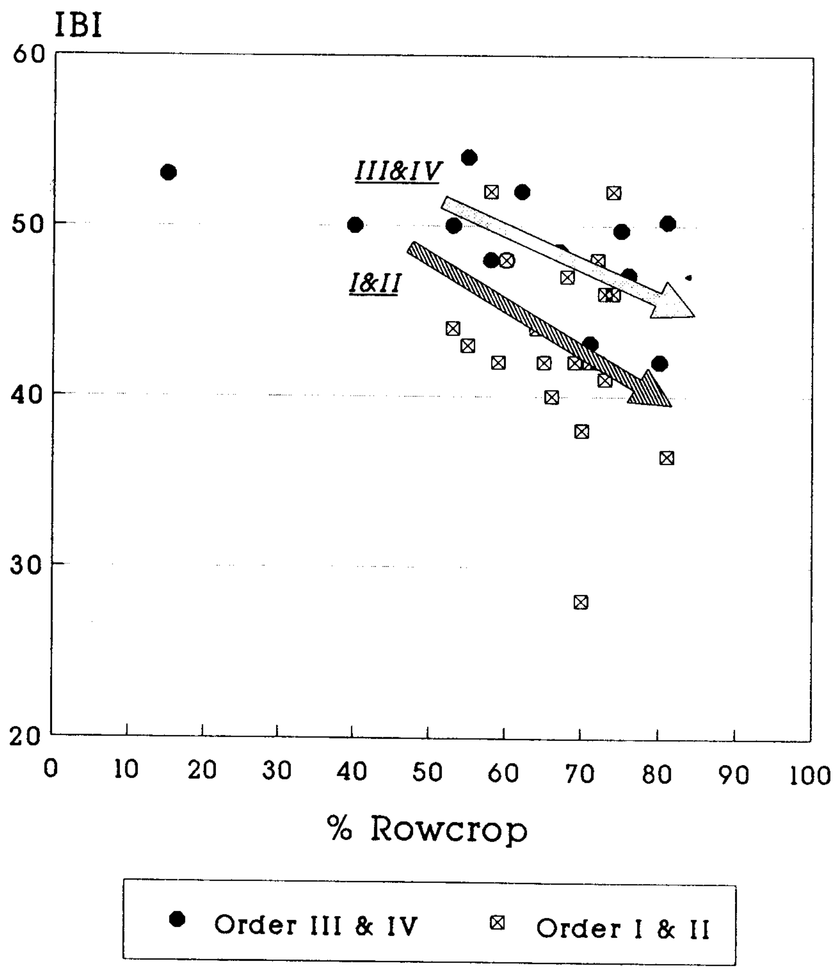

Figure 3: IBI values of fish communities as a function of rowcrop agriculture of the watersheds.

in the watershed of third and fourth order streams and the IBI. The IBI values decline steadily as the percentage of rowcrops increases, although there is much scatter among the data points. The general trends for smaller and larger streams, indicated by arrows, suggest that smaller streams are more strongly affected by progressively greater agricultural development. They also may be negatively influenced at lower rates of development, although watersheds in the 40% to 50% range are lacking.

Four of the stream systems originate in the Tipton Till Plain of Boone County, Indiana and flow in a generally south or southwesterly direction. Within 20 or so miles Sugar, Big Raccoon, and Big Walnut Creeks cut deeply into the plain creating a highly dissected landscape for varying distances. These portions of the watersheds are covered by a mature deciduous forest and are poorly suited for agriculture. The riparian protection thus afforded may be responsible in part for the continued maintenance of reasonably good fish communities in Sugar Creek.

All of the above streams, together with Eagle Creek, once supported healthy populations of smallmouth bass, sunfish, and darters. Sugar Creek still harbors them today (Gammon and Riggs 1983, Gammon et. al. 1990), but Big Walnut Creek and Eagle Creek contain only marginal populations (Benda and Gammon 1965, Fisher and Gammon 1981, 1982).

Big Raccoon Creek and some of its tributaries supported good populations 25 years ago (Gammon 1965), but darters, sunfish, and bass were lost sometime prior to 1981. From 1981 through 1989 three electrofishing collections each at eight stations were made for purposes of biologically monitoring a landfill (Gammon 1990). The landfill has had no measurable effect on the fish community, but agriculture has certainly impacted it. This data set is interesting because it demonstrates community changes in agricultural watersheds as affected by natural weather and flow patterns.

Table 2 summarizes IBI values for each station and year of study. Mean IBI values for the most downstream station are lower, perhaps because of occasional spring inundation by Mansfield Reservoir downstream. The other stations are remarkably similar to each other, but variability over time is quite striking with mean IBIs lowest in 1981 (IBI = 36.5) and highest in 1988 (IBI = 50.5).

The low IBI values from 1981 through 1984 probably resulted from poor reproduction and survival during unusually high water in the summers of 1979, 1981, and 1982. Darters, sunfish, and bass were virtually absent during those years (Figure 4) and a special seining effort in 1984 aimed at collecting darters also indicated very low population densities. The very high IBI values found in 1988 were associated with extremely low flows and a prolonged drought. Fish were undoubtedly concentrated and more vulnerable to capture.

Over the period of study the IBI values steadily increased, and so did the mean frequency of darters, sunfish, and bass. Figure 5 shows that while the mean IBI increased from less than 35 to more than 50 the mean number of darter, sunfish, and bass species captured per station increased from near zero to more than 2 in a linear fashion.

The weather and regime of stream flow are obviously influential. A succession of years with poor reproduction may decimate species populations which are merely marginal during good years. Conversely, a run of years favoring good reproduction may lead to the appearance of recovery. Generalizations concerning the "health" of a fish population based on investigations conducted during a single year

Table 2: IBI values based on three series of electrofishing collections at 8 stations from Big Raccoon Creek from 1981 to 1989.

Year	F1	F2	F3	F4	F5	F6	F7	F8	Mean
1981	36	38	38	36	38	34	36	36	36.5
1982	40	44	42	40	40	40	38	34	39.8
1984	48	44	42	46	44	40	40	40	43.0
1985	46	50	48	53	50	50	48	44	48.6
1986	40	40	40	38	42	38	40	36	39.3
1987	44	46	50	40	43	44	40	34	42.6
1988	52	48	50	52	50	50	52	52	50.5
1989	42	48	46	44	44	50	42	40	44.5
Mean	43.5	44.8	44.5	43.6	43.9	43.5	42.0	39.0	**43.1**

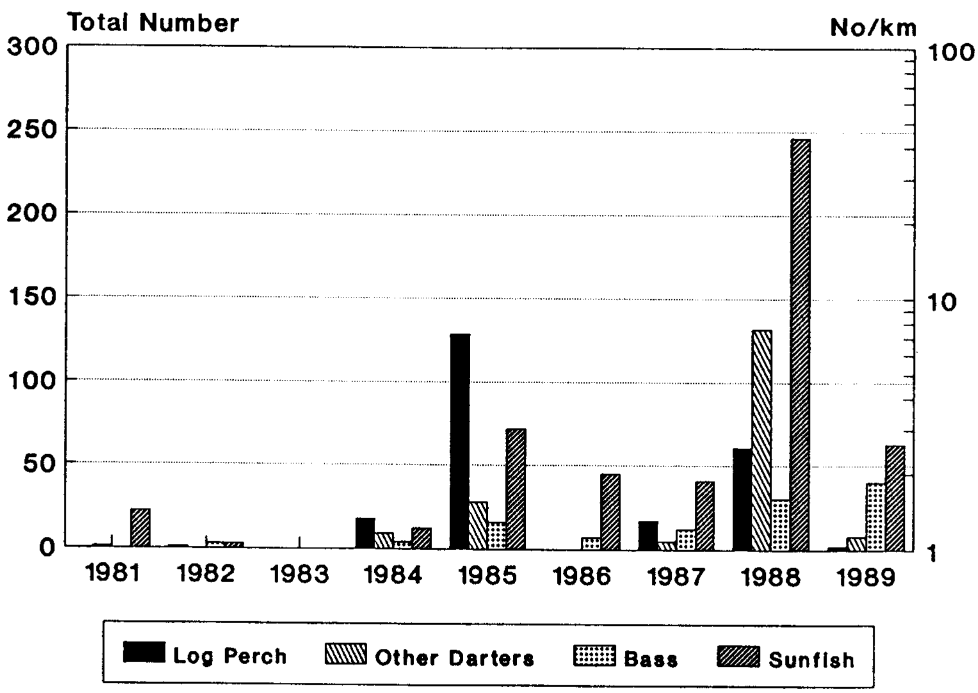

Figure 4: Total numbers of logperch, darters, sunfish, and bass collected in Big Raccoon Creek from 1981 through 1989.

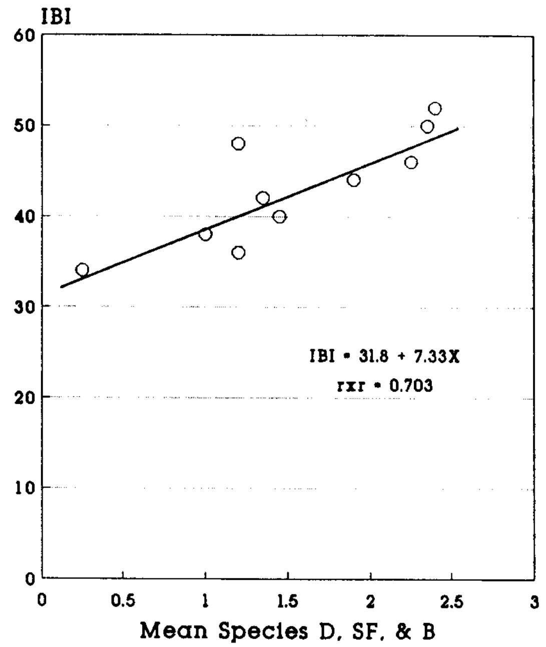

Figure 5: Relationship of catches of darters, sunfish, and bass to IBI values: Big Raccoon Creek 1981 through 1989.

would be unwise and tenuous. Unlike point-source influences which are more sustained and constant, agricultural nonpoint-source pollution is much more sporadic.

Rowcrop intensity has been used as a general measure of agricultural influence. The actual overall pattern of changes in fish communities is obscured and/or influenced by many factors other than agricultural land-use. Sporadic spills of fertilizer and feed lot wastes accelerate the process. Towns and industries may likewise reinforce the process through point-source contributions of wastes.

The pattern of fields relative to streams is no doubt of considerable importance. Streams which are well-protected by riparian vegetation are probably less susceptible to change than streams with tilled fields which extend to the stream banks and heavy lateral erosion. Lower Sugar Creek is strongly degraded by the effects of lateral erosion (Gammon and Riggs 1983), but not during all years (Gammon et. al. 1989).

Other environmental attributes unrelated to agriculture modify and/or influence the overall process in whole stream systems. The drainage pattern of the stream system is probably influential. Systems which are strongly linear with mostly small, low-order tributaries are likely to be more susceptible than more dendritic systems in which one or more less disturbed tributaries may serve as refugia which periodically replenish or restock a degraded mainstem during favorable periods.

Some of the agriculturally degraded tributaries of Sugar Creek appeared to contain better fish communities than they should have, probably because of the presence of good populations of fish in the mainstem and their migration during favorable periods. Upper Big Walnut Creek also contains a fairly good fish community despite being heavily rowcropped. All areas need to be examined for the pattern of permanent vegetation. Extensive agriculture may not be incompatible with good fish communities if adequate protection is afforded by a riparian buffer system.

Agriculture as an influence on streams has not received sufficient attention. There is a great need for programs to assess landuse activities throughout the state by GIS or comparable methodologies. Many of Indiana's streams have already been degraded by agriculture and even the better streams are in danger. We need to eliminate the pasturing of farm animals directly in streams. We need to develop programs for the enhancement of riparian buffers and stabilization of eroding banks.

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Dedication
The oral presentation of this research followed by six hours the birth of Robert Wayne Gammon-Pittman. May he and his entire generation enjoy clean rivers in the future.

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